(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(51) International Patent Classification⁷: C04B 28/02, E21B 33/13, C04B 28/08 // (C04B 28/02, 7:02, 22:14, 38:08), 201:20

(21) International Application Number: PCT/EP00/06459

(22) International Filing Date: 6 July 2000 (06.07.2000)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
99/09847   29 July 1999 (29.07.1999)   FR

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(81) Designated States (national): AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, CA, CH, CN, CU, CZ, DE, DK, EE, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MD, MG, MK, MN, MW, MX, NO, NZ, PL, PT, RO, RU, SD, SE, SG, SI, SK, SL, TJ, TM, TR, TT, UA, UG, US, UZ, VN, YU, ZW.

(84) Designated States (regional): ARIPO patent (GH, GM, KE, LS, MW, MZ, SD, SL, SZ, TZ, UG, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, GW, ML, MR, NE, SN, TD, TG).

Published:
— With international search report.

For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.

(54) Title: A LOW-DENSITY AND LOW-POROSITY CEMENTING SLURRY FOR OIL WELLS OR THE LIKE

(57) Abstract: The invention relates to a cement slurry for cementing an oil well or the like, the slurry having a density lying in the range 0.9 g/cm^3 to 1.3 g/cm^3, and being constituted by a solid fraction and a liquid fraction, having porosity (volume ratio of liquid fraction over solid fraction) lying in the range 38 % to 50 %. The solid fraction is constitued by a mixture of lightweight particles, microcement and optionally portland cement and gypsum. Such cements have remarkable mechanical properties due to their very low porosity in spite of having very low density.

A LOW-DENSITY AND LOW-POROSITY CEMENTING SLURRY FOR OIL
WELLS OR THE LIKE

The present invention relates to drilling techniques
for oil wells, gas wells, water wells, geothermal wells,
and the like. More precisely, the invention relates to
cementing slurries of low density and low porosity.

After an oil well or the like has been drilled,
casing or coiled tubing is lowered down the borehole and
is cemented over all or part of its height. Cementing
serves in particular to eliminate any fluid interchange
between the various formation layers that the borehole
passes through, preventing gas from rising via the
annulus surrounding the casing, or indeed it serves to
limit ingress of water into a well in production.
Naturally, another main objective of cementing is to
consolidate the borehole and to protect the casing.

While it is being prepared and then injected into
the well so as to be placed in the zone that is to be
cemented, the cementing slurry must present relatively
low viscosity and it must have rheological properties
that are practically constant. However, once it is in
place, an ideal cement would rapidly develop high
compression strength so as to enable other work on the
well that is being built to start again quickly, and in
particular so as to enable drilling to be continued.

The density of the cement must be adjusted so that
the pressure at the bottom of the well compensates at
least for the pore pressure in the geological formations
through which the well passes so as to avoid any risk of
eruption. As well as this lower limit on density, there
is also an upper limit. This upper limit is that the
hydrostatic pressure generated by the column of cement
plus the head losses due to the circulation of the fluids
being pumped must remain below the fracturing pressure of
the rocks in the section being cemented. Certain
geological formations are very fragile and require
densities close to that of water or even lower.

The risk of eruption diminishes with column height so the density required for compensating pore pressure is then lower. In addition, cementing a large height of column is advantageous since that makes it possible to

5   reduce the number of sections that are cemented. After a section has been cemented, drilling must be restarted at a smaller diameter, so having a large number of sections requires a hole to be drilled near the surface that is of large diameter, thereby giving rise to excess cost due to

10   the large volume of rock to be drilled and due to the large weight of steel required for the sections of casing, given their large diameters.

All of those factors favor the use of cement slurries of very low density.

15   The cement slurries in the most widespread use have densities of about 1900 kg/m^3, which is about twice the density desired for certain deposits. To lighten them, the simplest technique is to increase the quantity of water while adding stabilizing additives (known as

20   "extenders") to the slurry for the purpose of avoiding particles settling and/or free water forming at the surface of the slurry. Manifestly, that technique cannot get down to a density close to 1000 kg/m^3. Furthermore, hardened cements formed from such slurries have greatly

25   reduced compression strength, a high degree of permeability, and poor adhesive capacity. For these reasons, that technique cannot be used to go below densities of about 1300 kg/m^3 while still conserving good isolation between geological layers and providing

30   sufficient reinforcement for the casing.

Another technique consists in lightening the cement slurry by injecting gas into it (generally air or nitrogen) before it sets. The quantity of air or nitrogen added is such as to reach the required density.

35   It can be such as to form a cement foam. That technique provides performance that is a little better than the preceding technique since the density of gas is lower

than that of water, so less needs to be added.
Nevertheless, in oil industry applications density
remains limited in practice to densities greater than
1100 kg/m³, even when starting with slurries that have
5   already been lightened with water. Above a certain
"quality of foam", i.e. a certain ratio of gas volume to
volume of the foamed slurry, the stability of the foam
falls off very quickly, the compression strength of the
foam after it has set becomes too low, and its
10   permeability becomes too high, thereby compromising
durability in a hot aqueous medium which includes ions
that are aggressive to a greater or lesser extent for
cement.

An object of the present invention is to provide
15   cementing slurries that are more particularly adapted to
cementing oil wells or the like, having both low density
and low porosity, and that are obtained without
introducing gas.

According to the invention, this object is achieved
20   by a cement slurry for cementing an oil well or the like,
the slurry having a density lying in the range 0.9 g/cm³
to 1.3 g/cm³, in particular in the range 0.9 g/cm³ to
1.1 g/cm³, and being constituted by a solid fraction and a
liquid fraction, having porosity (volume ratio of liquid
25   fraction over solid fraction) lying in the range 38% to
50%, and preferably less than 45%.

The solid fraction is preferably constituted by a
mixture comprising:

· 60% to 90% (by volume) of lightweight particles
30   having a mean size lying in the range 20 microns (µm) to
350 µm;

· 10% to 30% (by volume) of micro-cement having a
mean particle diameter lying in the range 0.5 µm to 5 µm;

· 0 to 20% (by volume) of Portland cement, having
35   particles with a mean diameter lying in the range 20 µm
to 50 µm; and

· 0 to 30% (by volume) of gypsum.

The low porosities achieved make it possible to optimize mechanical properties and permeability. By presenting mechanical properties that are much better than those of conventional lightened systems, and

5 permeabilities that are lower, the leakproofing and adhesion properties of ultralightweight cement and the resistance of such formulations to chemical attack are thus much better than with the systems presently in use for low densities, even though the invention makes it

10 possible to reach densities that are exceptionally low, and in particular that are lower than the density of water. In addition, slurries of the invention do not require gas, thus making it possible to avoid the logistics that would otherwise be required for

15 manufacturing foamed cements.

The method of the invention is characterized in that particulate additives are incorporated in the cement slurry, such that in combination with one another and with the other particulate components of the slurry, and

20 in particular with the particles of micro-cement (or comparable hydraulic binder), they give rise to a grain-size distribution that significantly alters the properties of the slurry. The said particulate additives are organic or inorganic and they are selected for their

25 low density.

The low density is obtained by combining lightweight particles and cement (or a comparable hydraulic binder). Nevertheless, rheological and mechanical properties will only be satisfactory if the size of the particles and the

30 volume distribution thereof is selected in such a manner as to maximize the compactness of the solid mixture.

For a solid mixture having two components (the lightweight particles and the micro-cement), this maximum compactness is generally obtained for a volume ratio of

35 lightweight particles to micro-cement lying in the range 70:30 to 85:15, and preferably in the range 75:25 to 80:20, for lightweight particles selected to be of a size

that is at least 100 times approximately the size of the
particles of micro-cement, i.e. in general, particles
that are greater than 100 μm in size. These values can
vary, in particular as a function of the greater or
5   lesser dispersion in the grain-size distribution of the
lightweight particles. Particles having a mean size
greater than 20 microns can also be used, but performance
is not so good. Particles greater than 350 microns are
generally not used because of the narrow size of the
10   annular gaps to be cemented.

       Mixtures having three or more components are
preferred since they make it possible to obtain greater
compactness if the mean sizes of the various components
are significantly different. For example, it is possible
15   to use a mixture of lightweight particles having a mean
size of 150 microns, lightweight particles having a mean
size of 30 microns, and micro-cement, at a volume ratio
lying close to 55:35:10, or departing a little from these
optimum proportions, the mixture being constituted by 50%
20   to 60% (by volume) of the first lightweight particles of
mean diameter lying in the range 100 μm to 400 μm, 30% to
45% of the second lightweight particles of mean diameter
lying in the range 20 μm to 40 μm, and 5% to 20% of
micro-cement. Depending on the application, the fraction
25   of lightweight particles of intermediate size can be
replaced by Portland cement of ordinary size, in
particular class G Portland cement.

       The term "micro-cement" is used in the invention to
designate any hydraulic binder made up of particles of
30   mean size of about 3 μm and including no, or at least no
significant number of, particles of size greater than
10 μm. They have a specific surface area per unit weight
as determined by the air permeability test that is
generally about 0.8 m²/g.

35   The micro-cement can essentially be constituted by
Portland cement, in particular a class G Portland cement
typically comprising about 65% lime, 25% silica, 4%

alumina, 4% iron oxides, and less than 1% manganese
oxide, or equally well by a mixture of Portland micro-
cement with microslag, i.e. a mixture making use
essentially of compositions made from clinker comprising
45% lime, 30% silica, 10% alumina, 1% iron oxides and 5%
to 6% manganese oxide (only the principal oxides are
mentioned here; and these concentrations can naturally
vary slightly as a function of the supplier). For very
low temperature applications (< 30°C), Portland micro-
cement is preferable over a mixture of micro-cement and
slag because of its reactivity. If setting at right
angles is required, plaster (gypsum) can be used for all
or some of the middle-sized particles.

The lightweight particles typically have density of
less than 2 g/cm^3, and generally less than 0.8 g/cm^3. By
way of example, it is possible to use hollow
microspheres, in particular of silico-aluminate, known as
cenospheres, a residue that is obtained from burning coal
and having a mean diameter of about 150 µm. It is also
possible to use synthetic materials such as hollow glass
beads, and more particularly preferred are beads of
sodium-calcium-borosilicate glass presenting high
compression strength or indeed microspheres of a ceramic,
e.g. of the silica-alumina type. These lightweight
particles can also be particles of a plastics material
such as beads of polypropylene.

In general, the density of the slurry is adjusted
essentially as a function of which lightweight particles
are chosen, but it is also possible to vary the ratio of
water to solid (keeping it in the range 38% to 50% by
volume), the quantity of micro-cement or of comparable
hydraulic binder (in the range 10% to 30%), and adding
Portland cement of ordinary size as a replacement for a
portion of the lightweight particles.

Naturally, the slurry can also include one or more
additives of types such as: dispersants; antifreeze;
water retainers; cement setting accelerators or

retarders; and/or foam stabilizers, which additives are
usually added to the liquid phase, or where appropriate
incorporated in the solid phase.

5   Formulations made in accordance with the invention
have mechanical properties that are significantly better
than those of foamed cements having the same density.
Compression strengths are very high and porosities very
low. As a result, permeabilities are smaller by several
orders of magnitude than those of same-density foamed
10   cements, thereby conferring remarkable properties of
hardness on such systems.

The method of the invention considerably simplifies
the cementing operation, since it avoids any need for
logistics of the kind required for foaming.

15   Slurries prepared in accordance with the invention
also have the advantage of enabling all of the
characteristics of the slurry (rheology, setting time,
compression strength, ...) to be determined in advance
for the slurry as placed in the well, unlike foamed
20   slurries where certain parameters can be measured on the
slurry only prior to the introduction of gas (setting
time).

The following examples illustrate the invention
without limiting its scope.
25

EXAMPLE 1

Low-density and low-porosity slurries can be
obtained from mixtures of particles of two or three (or
even more) different sizes, so long as the packing volume
30   fraction (PVF) is optimized.

The properties of three slurries prepared in
accordance with the invention are described and compared
with those of a conventional low-density extended slurry
and of a foamed system:

35   Slurry A: A mixture of powders was prepared. It
comprised 55% by volume of hollow spheres taken from
cenospheres having an average size of 150 microns

(specific gravity 0.75); 35% by volume of glass
microspheres having an average size of 30 microns; and
10% by volume of a mixture of Portland micro-cement and
slag having a mean size of about 3 microns.

5   The microspheres used are sold by 3M™ under the name
Scotchlite S60/10,000; such microspheres have a density
of 0.6 g/cm³ and a grain-size distribution such that 10%
of the particles (by volume) have a size of less than
15 µm, 50% less than 30 µm, and 90% less than 70 µm;

10   these particles were selected in particular because of
their high compression strength (90% of the particles
withstand isostatic compression of 68.9 MPa or
10,000 psi).

          Water and the following additives were mixed with

15   this powder so as to ensure that the volume percentage of
liquid in the slurry was 42%: water retainer based on 2-
acrylamido 2-methylpropane sulfonic acid (AMPS) at 0.2%
(percent by weight of powder, i.e. all of the solid
particles taken together (micro-cement, microspheres and

20   cenospheres for this slurry A)); an antifoaming agent at
0.03 gallons per bag of powder; and a super-plasticizer
based on polynaphthalene sulfonate at 0.07 gallons per
bag of powder. It should be observed that a bag of
powder is defined by analogy with bags of cement as being

25   a bag containing 45.359 kg of mixture, in other words
1 gpb = 0.03834 liters (/) of additive per kg of mixture.

          Slurry B: A mixture of powders was prepared. It
comprised 78% by volume of hollow spheres obtained from
cenospheres having a mean size of 150 microns and a

30   density of 0.63 g/cm³, and 22% by volume of a mixture of
Portland micro-cement and slag having a mean size of
about 3 microns.

          Water and the following additives were mixed with
the powder so that the volume percentage of liquid in the

35   slurry was 42%: water retainer based on AMPS polymer at
0.2% by weight of powder; antifoaming agent at 0.03
gallons per bag of powder; and a super-plasticizer based

on polynaphthalene sulfonate at 0.1 gallons per bag of
powder.

Slurry C: A mixture of powders was prepared. It
comprised 78% by volume of Scotchlite glass microspheres
having a mean size of 30 microns, and 22% by volume of a
mixture of Portland micro-cement and slag having a mean
size of about 3 microns.

Water and the following additives were mixed with
said powder so that the volume percentage of liquid in
the slurry was 45%: water retainer based on AMPS polymer
at 0.2% by weight of powder; an antifoaming agent at 0.03
gallons per bag of powder; and a super-plasticizer based
on polynaphthalene sulfonate at 0.145 gallons per bag of
powder.

Slurry D: A mixture of powders was prepared. It
comprised 78.4% by volume of hollow spheres derived from
cenospheres having a mean size of 150 microns (density
0.72 g/cm^3) and 21.6% by volume of glass G Portland
cement.

Water and the following additive were mixed with
said powder so that the volume percentage of liquid in
the slurry was 57%: an antifoaming agent at 0.03 gallons
per bag of powder.

Slurry E: A conventional slurry of density
1900 kg/cm^3 was prepared based on a class G Portland
cement.

The slurry was foamed with a quantity of foam of 50%
so as to obtain a slurry whose final density was
950 kg/m^3.

Slurry	A	B	C	D	E
Density	924 (7.7)	1068 (8.9)	1056 (8.8)	1130 (9.4)	950 (7.9)
Porosity	42%	42%	45%	57%	78%*
PV	87	68	65		
Ty	3.7 (7.7)	8.6 (18)	3.4 (7.2)		
CS	11.7 (1700)	19.3 (2800)	14.5 (2100)	2.48 (360)	4.62 (670)

The densities are expressed in kg/m³ (and in pounds per gallon in parentheses). Rheology is expressed by a
5   flow threshold Ty in Pascals (and in pounds per 100 square feet in parentheses), and by plastic viscosity in mPa.s or centipoise, using the Bingham fluid model. These parameters were determined at ambient temperature. CS means compression strength after 24 hours for cement
10   set at 60°C (140°F) at a pressure of 6.9 MPa (1000 psi), and it is expressed in Mpa (and in pounds per square foot in parentheses).
       * In this case, porosity was calculated as volume of gas + water over total volume of the slurry.
15   It can be seen that for the slurries prepared in accordance with the invention, compression strength is particularly high for densities that are so low and that these slurries present excellent rheology in spite of their low porosity.
20

EXAMPLE 2
       For slurries having a density greater than 8 pounds per gallon (ppg), a portion of the lightweight particles can be substituted by class G cement.
25   Slurry A: A mixture of powders was prepared. It comprised 55% by volume hollow spheres derived from cenospheres having a mean size of 150 microns, 35% by

volume of Scotchlite glass microspheres having a mean
size of 30 microns, and 10% by volume of a mixture of
Portland micro-cement and slag having a mean size of
about 3 microns.

Water and the following additives were mixed with
the powder so that the volume percentage of the liquid in
the slurry was 42%: water retainer based on AMPS polymer
at 0.2% by weight of powder; an antifoaming agent at 0.03
gallons per bag of powder; and a super-plasticizer based
on polynaphthalene sulfonate at 0.07 gallons per bag of
powder.

Slurry B: A mixture of powders was prepared. It
comprised 55% by volume of hollow spheres derived from
cenospheres having a mean size of 150 microns, 25% by
volume of Scotchlite glass microspheres having a mean
size of 30 microns, 10% by volume of a class G Portland
cement, and 10% by volume of a mixture of Portland micro-
cement and slag having a mean size of about 3 microns.

Water and the following additives were mixed with
the powder so as obtain a volume percentage of liquid in
the slurry of 42%: water retainer based on AMPS polymer
at 0.2% by weight of powder; an antifoaming agent at 0.03
gallons per bag of powder; and a super-plasticizer based
on polynaphthalene sulfonate at 0.01 gallons per bag of
powder.

Slurry C: A mixture of powders was prepared. It
comprised 55% by volume of hollow spheres derived from
cenospheres having a mean size of 150 microns, 20% by
volume of Scotchlite glass microspheres having a mean
size of 30 microns, 15% by volume of a class G Portland
cement, and 10% by volume of a mixture of Portland micro-
cement and slag having a mean size of about 3 microns.

Water and the following additives were mixed with
the powder so that the volume percentage of liquid in the
slurry was 42%: water retainer based on AMPS polymer at
0.2% by weight of powder; an antifoaming agent at 0.03
gallons per bag of powder; and a super-plasticizer based

on polynaphthalene sulfonate at 0.01 gallons per bag of powder.

Slurry D: A mixture of powders was prepared. It comprised 55% by volume of hollow spheres derived from
5   cenospheres having a mean size of 150 microns, 15% by volume of Scotchlite glass microspheres having a mean size of 30 microns, 20% by volume of a class G Portland cement, and 10% by volume of a mixture of Portland micro-cement and slag having a mean size of about 3 microns.
10   Water and the following additives were mixed with the powder so as to obtain a volume percentage of liquid in the slurry of 42%: water retainer based on AMPS polymer at 0.2% by weight of powder; an antifoaming agent at 0.03 gallons per bag of powder; and a super-
15   plasticizer based on polynaphthalene sulfonate at 0.01 gallons per bag of powder.

          Densities are expressed in kg/m^3 (and in pounds per gallon in parentheses). Rheology is expressed by the flow threshold Ty in Pascals (and in pounds per 100
20   square feet in parentheses), and by plastic viscosity PV in mPa.s or centipoise, using the Bingham fluid model. These parameters were determined at ambient temperature. CS stands for compression strength after 24 hours and after 48 hours for cement setting at 60°C at a pressure
25   of 6.9 MPa (1000 psi), expressed in MPa (and in pounds per square foot in parentheses).

Slurry	A	B	C	D
Density	924 (7.7)	1068 (8.9)	1140 (9.5)	1218 (10.15)
Porosity	42%	42%	42%	42%
PV	87	90	100	109
Ty	7.7	8.8	9.0	11.2
CS (24 h)	7.58 (1100)	18.3 (2650)	19.7 (2850)	20.7 (3000)
CS (48 h)	9.0 (1300)	19.0 (2750)	29.7 (4300)	28.3 (4100)

Adding Portland cement as a portion of the "medium-
sized" particles makes it possible to cover the entire
range of densities from 8 ppg to 11 ppg and significantly
improves compression strength. This addition does not
disturb the good rheological properties in any way.

EXAMPLE 3
For slurries having a density greater than 8 ppg, a
portion of the lightweight particles can be substituted
by micro-cement or by a mixture of micro-cement and slag.
Slurry A: A mixture of powders was prepared. It
comprised 55% by volume hollow spheres derived from
cenospheres having a mean size of 150 microns, 30% by
volume of Scotchlite glass microspheres having a mean
size of 30 microns, and 15% by volume of a mixture of
Portland micro-cement and slag having a mean size of
about 3 microns.
Water and the following additives were mixed with
the powder so that the volume percentage of the liquid in
the slurry was 42%: water retainer based on AMPS polymer
at 0.2% by weight of powder; an antifoaming agent at 0.03
gallons per bag of powder; and a super-plasticizer based
on polynaphthalene sulfonate at 0.07 gallons per bag of
powder.

Slurry B: A mixture of powders was prepared. It comprised 55% by volume hollow spheres derived from cenospheres having a mean size of 150 microns, 25% by volume of Scotchlite glass microspheres having a mean
5   size of 30 microns, and 20% by volume of a mixture of Portland micro-cement and slag having a mean size of about 3 microns.

Water and the following additives were mixed with the powder so that the volume percentage of the liquid in
10   the slurry was 42%: water retainer based on AMPS polymer at 0.2% by weight of powder; an antifoaming agent at 0.03 gallons per bag of powder; and a super-plasticizer based on polynaphthalene sulfonate at 0.07 gallons per bag of powder.

15

Slurry	A	B
Density	990 (8.25)	1056 (8.8)
Porosity	42%	42%
CS (24 h)	11.2 (1630)	21.4 (3100)
CS (48 h)	11.7 (1700)	22.1 (3200)

Densities are expressed in kg/m^3 (and in pounds per gallon in parentheses). CS means compression strength after 24 hours and 48 hours for cement set at 60°C under
20   a pressure of 6.9 MPa (1000 psi), expressed in MPa (and in pounds per square foot in parentheses).

Increasing the content of micro-cement and slag mixture gives rise to exceptional compression strength performance at 9 ppg.

25

EXAMPLE 4

Depending on the desired mechanical properties (flexibility, ability to withstand high pressures), various lightweight particles can be used so long as the
30   PVF is optimized.

Slurry A: A mixture of powders was prepared. It comprised 55% by volume hollow spheres derived from cenospheres having a mean size of 150 microns, 30% by volume of hollow spheres derived from cenospheres having a mean size of 45 microns, and 15% by volume of a mixture of Portland micro-cement and slag having a mean size of about 3 microns.

Water and the following additives were mixed with the powder so that the volume percentage of the liquid in the slurry was 42%: water retainer based on AMPS polymer at 0.2% by weight of powder; an antifoaming agent at 0.03 gallons per bag of powder; and a super-plasticizer based on polynaphthalene sulfonate at 0.07 gallons per bag of powder.

Slurry B: A mixture of powders was prepared. It comprised 55% by volume of particles of polypropylene having a means size of 300 microns, 30% by volume of Scotchlite glass microspheres having a mean size of 30 microns, and 15% by volume of a mixture of Portland micro-cement and slag having a mean size of about 3 microns.

Water and the following additives were mixed with the powder so that the volume percentage of the liquid in the slurry was 42%: a retarder based on purified lignosulfonates at 0.22% by weight of powder; a water retainer based on AMPS polymer at 0.2% by weight of powder; and a super-plasticizer based on polynaphthalene sulfonate at 0.05 gallons per bag of powder.

Slurry	A	B
Density	990 (8.25)	1068 (8.9)
Porosity	42%	42%
PV	93	116
Ty	20	9.3
CS (24 h)	18.3 (2640)	10.3 (1500)*
CS (48 h)	18.7 (2700)	22.1 (3200)*

Densities are expressed in kg/m³ (and in pounds per gallon in parentheses). Rheology is expressed by the flow threshold Ty in Pascals (and in pounds per 100

5   square feet in parentheses), and by plastic viscosity PV in mPa.s or centipoises, using the Bingham fluid model. These parameters were determined at ambient temperature. CS means compression strength at 24 hours and at 48 hours from the cement setting at 60°C under 6.9 MPa (1000 psi),

10 expressed in MPa (and in pounds per square foot in parentheses).

* Compression strength at 24 hours for cement set at 104°C (220°F) under a pressure of 20.7 MPa (3000 psi), expressed in MPa and in psi in parentheses.

15

EXAMPLE 5

For low temperature applications, the mixture of micro-cement and slag can be substituted by pure micro-cement, or plaster can be added to replace the medium-

20 sized particles.

We have compared a formulation of the invention with a foamed plaster formulation.

Slurry A: A mixture of powders was prepared. It comprised 42.7% by volume of hollow spheres derived from

25 cenospheres having a mean size of 150 microns, 20% by volume of hollow spheres derived from cenospheres having a mean size of 45 microns, 27.3% by volume of gypsum, and 10% by volume of a mixture of Portland micro-cement and slag having a mean size of about 3 microns.

30 Water and the following additives were mixed with the powder so that the volume percentage of liquid in the slurry was 42%: retarder based on purified lignosulfonates at 0.05 gallons per bag of powder; a water retainer of the example at 0.04 gallons per bag of

35 powder; and an antifoaming agent at 0.03 gallons per bag of powder.

Slurry B (reference): This slurry corresponds to the prior art. A mixture of powders was prepared. It comprised 40% by volume of class G cement and 60% by volume of plaster. Water and additives were mixed with the powder so that the density of the slurry was 1900 kg/m³ (15.8 ppg).

To foam this slurry, entirely conventional wetting agents were added: D138 and F052.1 in a 1:1 ratio. The quantity added depends on foam quality. It was adjusted so as to obtain a slurry having a density of 1320 kg/m³ (11 pounds per gallon).

Densities		1320 (11)	1218 (10.15)
Slurry A (of the invention)	Q		0
	PV		112
	Ty		6.7
	CS (at 12 hours for cement set at 4°C under 6.9 MPa)		2.41 (350)
	CS (at 24 hours for cement set at 25°C under 6.9 MPa)		14.8 (2150)
Slurry B (reference)	Q	30%	
	CS (at 24 hours for cement set at 18°C under atmospheric pressure)	2.96 (430)	
	CS (at 48 hours for cement set at 18°C under atmospheric pressure)	4.55 (660)	

Densities are expressed in kg/m³ (and in pounds per gallon in parentheses). Rheology is expressed by the flow threshold Ty in Pascals (and in pounds per 100 square feet in parentheses), and by plastic viscosity PV in mPa.s or centipoises, using the Bingham fluid model.

These parameters were determined at ambient temperature.
CS stands for compression strength under conditions
stated in the table, expressed in MPa (and in pounds per
square foot in parentheses).

CLAIMS

1/ A cement slurry for cementing an oil well or the like,
the slurry having a density lying in the range 0.9 g/cm³
to 1.3 g/cm³, and being constituted by a solid fraction
5   and a liquid fraction, having porosity (volume ratio of
liquid fraction over solid fraction) lying in the range
38% to 50%, said solid fraction comprising :

· 60% to 90% (by volume) of lightweight particles having
10   a mean size lying in the range 20 microns (µm) to 350 µm;
        · 10% to 30% (by volume) of micro-cement having a
mean particle diameter lying in the range 0.5 µm to 5 µm;
        · 0 to 20% (by volume) of Portland cement, having
particles with a mean diameter lying in the range 20 µm
15   to 50 µm; and
        · 0 to 30% (by volume) of gypsum.

2/ A cement slurry according to claim 1, characterized by
porosity of less than 45%.
20

3/ A cement slurry according to any preceding claim,
characterized in that said lightweight particles have a
density of less than 2 g/cm³, and preferably less than
0.8 g/cm³.
25

4/ A cement slurry according to claim 3, characterized in
that said lightweight particles are selected from hollow
microspheres, in particular silico-aluminate microspheres
or cenospheres, synthetic materials such as hollow glass
30   beads, and more particularly beads of sodium-calcium-
borosilicate glass, ceramic microspheres, e.g. of the
silica-alumina type, or beads of plastics material such
as polypropylene beads.

35   5/ A cement slurry according to any preceding claim,
characterized in that the slurry has one or more
additives of the following types: dispersants,

antifreeze, water retainers, cement setting accelerators
or retarders, and foam stabilizers.

6/ A cement slurry according to any preceding claim,
5   characterized in that the solid fraction of the slurry is
constituted by lightweight particles of diameter lying in
the range 100 μm to 350 μm and by particles of micro-
cement, with the ratio of lightweight particles to micro-
cement lying in the range 70:30 to 85:15.
10

7/ A cement slurry according to any one of claims 1 to 6,
characterized in that the solid fraction of the mixture
is constituted by 50% to 60% (by volume) of first
lightweight particles having a mean diameter lying in the
15   range 100 μm to 400 μm, by 30% to 45% of second
lightweight particles of mean diameter lying in the range
20 μm to 40 μm, and by 5% to 20% of micro-cement.

8/ Use of the slurry according to any preceding claim in
20   cementing oil, gas, or similar wells.

INTERNATIONAL SEARCH REPORT

A. CLASSIFICATION OF SUBJECT MATTER

IPC 7   C04B28/02   E21B33/13   C04B28/08   //(C04B28/02,7:02,22:14, 38:08),C04B201:20

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC 7   C04B   E21B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
P,X	WO 00 29351 A (SOFITECH NV ;SCHLUMBERGER CA LTD (CA); SCHLUMBERGER CIE DOWELL (FR)) 25 May 2000 (2000-05-25) page 3, line 33 -page 4, line 14 ---	1-8
Y	US 3 804 058 A (MESSENGER J) 16 April 1974 (1974-04-16) claims; table II ---	1,3-6,8
Y	US 5 571 318 A (GRIFFITH JAMES E ET AL) 5 November 1996 (1996-11-05) column 8, line 33 - line 64; example 2 ---	1,3-6,8
A	GB 2 027 687 A (STANDARD OIL CO) 27 February 1980 (1980-02-27) page 3, line 38 -page 4, line 2; claims ---	1,3-8

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[X] Further documents are listed in the continuation of box C.   [X] Patent family members are listed in annex.

° Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
6 November 2000	14/11/2000

Name and mailing address of the ISA	Authorized officer
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INTERNATIONAL SEARCH REPORT

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT		
Category °	Citation of document, with indication,where appropriate, of the relevant passages	Relevant to claim No.
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